Assessment Result and Analysis on Teaching of Control Systems Course (ELEC 431) in Electrical Engineering Department (United Arab Emirates University)

Addy Wahyudie

***Abstract*— This paper discusses the assessment result and analysis of teaching Control Systems (ELEC 431) course in Electrical Engineering Department of United Arab Emirates University. The assessment is conducted using two inputs: the assessment tools (exams, quizzes, homework, project) and the student's perception about their own achievement over the course. The assessments were conducted from Fall 2011-Fall 2014 or within four cycle of course's offering. The study shows the continuous corrective actions within the course and its effect. In this study, we only consider the attainment of design aspect of the course. The attainment of the student regarding the design is tending to increase. We also recorded the level of student satisfaction for the course and its instructor using the comparative study questioners. The result shows that the students appreciate the course and the instructor and the result is above the average of department and collage.**

***Index Terms*— Assessment result, control system engineering course, learning outcome, assessment based on ABET.**

I. INTRODUCTION

The assessment for a course is an important tool to measure the level of understanding for the students. In this study, we present the assessment result for student's attainments based on ABET for the Control Systems (ELEC 431) in United Arab Emirates University. Similar studies for the Control Systems course can be found in [1,2]. The similar studies that were conducted in the Middle East can be found in [3,4]. More studies on assessment for electrical courses are given in [4-9].

This paper shares the assessment results for the design aspect in the course of Control Systems (ELEC 431) in Electrical Engineering Department of United Arab Emirates University. The continuous corrective action is presented to increase the level of attainment for the students. The assessment is conductive using two inputs: assessment tools and student own perception about the course.

The paper is organized as follows. In the section of course description, we describe the detail of the course. We present and discuss the results in the section of Result and Discussion. Finally, we give the conclusion in the section of Conclusion.

II. COURSE DESCRIPTION

This study was conducted to find outcome the assessment results for two different classes (sections) for the same courses at the same offering. Here, we assessed the course for two offerings. The course is only offered once a year, which is fall semester. Two different instructors taught the course. However, we assured that the teaching quality of the course quite similar as we shared the same course contents, slides, and assessment tools. The following is the detail of the course:

A. Participant

We analyze the course in the last two offering. Table 1 presents the number of the students for the offerings.

Table 1: Number in each sampled offerings

Academic Year	Number of students
Fall 2011	52
Fall 2012-2013	50
Fall 2013-2014	39
Fall 2014-2015	51

B. Course Description

The course catalogue for ELEC 431 can be found in UAE-U website, as the following: Control systems in the real world, feedback concept, modeling of electromechanical systems, block diagrams, steady-state error analysis, stability analysis, time-domain analysis of control systems, root-locus, frequency domain analysis of control systems, control systems design in the frequency domain (phase lead and phase lag compensation, Nyquist and Nichols charts), and proportional-integral-derivative (PID) control.

C. Course Learning Outcomes (CLOs)

The CLOs are composed based on the course catalogue. The CLO have designed appropriately and gone through many necessary revisions to meet the ABET program-learning outcome (PLO) as follows:

1. Derive mathematical model of systems [a,e].
2. Analyze time response of the first order systems, second order systems, and higher order systems [c, e].
3. Simplify multiple subsystems [e].
4. Evaluate the stability of the closed-loop systems [c,e].
5. Evaluate steady-state error of systems [c,e].
6. Analyze systems using frequency techniques [a,c].
7. Design controller for systems [c,d,g].

The program-learning outcomes (PLOs) for the department of Electrical Engineering are stated as the following:

(a) Ability to apply knowledge of mathematics, statistics, science and engineering principles. The mathematics knowledge includes linear algebra, vector algebra, partial differential equations, complex analysis, and probability.

Addy Wahyudie received the B. Eng. degree in electrical engineering (majoring control systems) with cum-laude distinction in 2002 from Gadjah Mada University, Indonesia

(b) Ability to design and conduct experiments safety, as well as to analyze and interpret data.
(c) Ability to design electrical components, systems or process to meet desired specifications and imposed constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
(d) Ability to work in teams including multidisciplinary teams.
(e) Ability to identify, formulate and solve problems encountered in the practice of electrical engineering.
(f) Understanding of professional and ethical responsibility.
(g) Ability to communicate effectively orally and in writing.
(h) Ability to understand the impact of engineering solutions in a global and societal context.
(i) Recognition of the need for, and ability to engage in life-long learning.
(j) Knowledge of contemporary issues.
(k) Ability to use the techniques, skills, and modern engineering tools necessary for electrical engineering practice.

D. Tentative Weekly Schedule and the Detail Course Content

The tentative weekly schedule to accomplish the course content is depicted in Table 2.

Table 2: Tentative Weekly Schedule

Week	Session content	Assignments
Week 1	**Topic: Introduction to control systems** **Content:** History of control systems; systems configuration; Analysis & design objectives.	-
Week 2	**Topic: Modeling in frequency domain** **Content:** Laplace transform; Transfer function; Transfer function for electrical & mechanical systems.	**HW 1**
Week 3	**Topic: Modeling in time-domain** **Content:** State-space representation; Converting state-space to transfer function and vice-versa.	**HW 2 & Quiz 1**
Week 4	**Topic: Time response** **Content**: Poles, zeros, and system response of first order system.	**Quiz 2**
Week 5	**Topic: Time response** **Content:** System response of second order systems; Higher order systems; System response with zeros.	**HW 3**
Week 6	**Topic: Stability** **Content:** Routh-Hurwitz criterion; Routh-Hurwitz criterion for special cases.	**Quiz 3 and HW 4**
Week 7	**Topic: Reduction of multiple subsystems** **Content:** Block diagram reduction.	**Quiz 4**
Week 8	**Topic:** - **Content:** -	**Test 1 & Midterm**
Week 9	**Topic: Reduction of multiple subsystems** **Content:** Block diagram reduction (Cont.).	**HW 5**
Week 10	**Topic: Steady-state error** **Content:** Steady-state error for unity/non-unity feedback systems; Static error constant and system's type.	**HW 6 & Quiz 5**
Week 11	**Topic: Frequency response techniques** **Content:** Bode plot and Nyquist diagram.	**HW 7 & Quiz 6**
Week 12	**Topic: PID and design via root locus** **Content:** The concept of PID; Ideal PI design.	**HW 8 & Quiz 7**
Week 13	**Topic: PID and design via root locus** **Content:** Ideal PD design.	**HW 9 & Quiz 8**
Week 14	**Topic: PID and design via root locus** **Content:** Lead and Lag compensators.	**Quiz 9**
Week 15	**Topic: Project** **Content:** -	**Test 2 & Presentation**
Week 16	**Topic: Review** **Content:** -	

E. Assessment tools

The CLOs were measured quantitatively based on students' performances in the course through the designed assessment tools. These assessment tools are shown in Table 3.

Table 3: Assessment tools and its percentage contribution

Activities contribution to grades	% Contribution
Weekly Homework	5%
Quizzes	5%
Project	10%
Test 1 (before midterm)	10%
Test 2 (after midterm)	10%
Midterm exam	25%
Final exam	35%

The weights in the Table 3 are appropriate and proportional to the time student get for the preparation and the level of difficulty. The final exam and midterm exam have the highest weights of 35% and 25%, respectively. They are comprehensive exams and cover complete course material through during semester. In this course, we divide the covering material for the midterm (and its Test 1) and final exams (and its Test 2) for reducing the load for the students. The material for the midterm is covering the CLO #1 to CLO #3. These CLOs will not be assessed again the final exam.

E. Appropriateness of textbooks and other learning resources.

The textbook of the course is Control Systems Engineering (6^{th} edition) by Norman Nise (Wiley & Sons). The textbook is one of the best textbooks to teach the basic of control system engineering.

F. Appropriateness of prerequisites.

The prerequisite of the course is ELEC 305 (Signal and Systems) and MATH 2220 (Linear Algebra and Engineering applications). ELEC 305 provides fundamental for the discussion in frequency domain, while ELEC 2220 gives fundamental for discussion in time domain.

III. Result and Discussion

In this section we only discuss the attainment of the PLO [c] which is "Ability to design electrical components, systems or process to meet desired specifications and imposed constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability". We analyzed the attainment using two inputs: the assessment tools and the perception of the students. In the analyzing using the assessment tools, the student worked is graded and analyzed using special software to map the graded worked into the scale of 1 (lowest) to 5 (highest). While in the perception of the student, a questioner is distributed among the student to ask what is their level of understanding regarding the course's PLO. The same with the assessment over the assessment tools, the students graded their perception of understanding within the scale of 1 (lowest) to 5 (highest).

The assessment results for the course from academic year of Fall 2011 to Fall 2014 based on the two inputs are summarized in the table 4.

Table 4: Assessment results for PLO [c]

Semester Year	Assessment From Student	Assessment From Assessment Tools
Fall 2011	3.9	3.6
Fall 2012	4.3	3.9
Fall 2013	4.4	4.1
Fall 2014	4.2	4.0

The following is the detail of the assessment results, the corrective action, and then results of corrective action:

A. Fall 2011

Suggested corrective action of the previous offering and their results:

In the last offering for the course, the instructor suggested to give more efforts on explaining in the part of design. The suggestive action has been applied. The students seem to have better understanding in the concepts. This has been proved by the result of the quantitative assessment.

Current semester assessment:

Many examples and assignments have been given to the students. The results of the assessments meet the target. The concepts of the design are spread within the chapter of Stability, Steady-State Error, Frequency Response, and PID Design.

Suggested corrective action for the next offering:

The quantitative assessment shows the result is slightly above the target. It is desire to increase the level of understanding in the design part of the course. More efforts must be taken by giving more challenging home works and quizzes. This will force the student to prepare their exams. From the instructor side, continuous improvements in the teaching can be achieved by better preparation of the lecture. This is implemented by improving the quality of the slides. In addition, it is good to add more techniques in PID tuning. Classical PID tuning using root-locus will be added in the next offering

Continuous Improvement Analysis:

There are two continuous improvements in this course:

1. Maintaining and improving the level of understanding over the concepts of design in control engineering by improving the quality of the teaching and assignments.
2. Enrichment the existing material for the design techniques in control engineering. Obviously, this effort will be limited by the time allocation (3 credit hours per week) and the syllabus/course contain for the course. The enrichment will be stable at some points. Additional method in PID tuning will be added in the next offering.

B. Fall 2012:

Suggested corrective action of the previous offering and their results:

In this semester, the instructor successfully enriched the material in PID design. The new control technique using root-locus is introduced in the course. The new control technique enables the user to design the specification of transient response and state-state error. This feature cannot be obtained using the conventional Broida and Ziegler-Nichols techniques. The student can understand the concept well and can apply it to solve their design problem. The better quality of assignments and teaching seem to increase the level of understanding of the class. This can be seen in the increasing of quantitative result comparing to the last offering.

Current semester assessment:

The quantitative result shows there is an increasing index in the result. Therefore, the students have the good response with the additional control technique. The additional examples and tutors are conducted throughout the semester to help the student to pass their exam.

Suggested corrective action for the next offering:

Quality of the teaching needs to be kept increasing. Similar in the last offering, this can be achieved by designing good assignments. It will be interesting if we can have a small project that summarized everything from this course from analysis until design phase. The project will ask the student to pick a real plant of the system, model it, analyze it, decide the design specifications, calculate it, and test the performance of the system whether it meet the design specifications. Therefore, there is link between analyzing part (outcome E) to designing phase (outcome C). In the next year, the software Matlab will be utilized to help student to analyze and design in the course. In the next offering, the target of quantitative level of the design will be increased to 4 or 80%.

Continuous Improvement Analysis:

The corrective actions improve the quality of the course in this semester. There are few things can be done to have a continuous improvement in the next offering:

1. Maintaining the level of understanding in the concepts by improving the teaching in the class. This will be implemented by giving more time on examples, tutorial, term project, programming tool, etc.

2. Increasing the quantitative result to 4 or 80%.

C. Fall 2013:

Suggested corrective action of the previous offering and their results:

In this semester, the course project in designing ideal PID/lead-lag controller is conducted. The assigned point for the project is 10% from the total points. The student has to select the real/actual system to derive its transfer function and analyze its transient performance, as well as its stability, and steady-state performance. Using the previous information, the student is expected to increase the performance of the system by designing the PID / lead-lag controller using Ziegler-Nichols, Broida, and root-locus techniques. The majority of the class can fulfill the project requirements. There was a group student that used their topic in their graduation project for this project. The quantitative target is met although the index is increase compare to the last offering.

Current semester assessment:

The quantitative result shows the class reaches its targeted index. Through the course project, the student feels the benefits of having the course project that covers all material of the course before its final exam. The students gained better understanding and preparation to pass their final exam.

Suggested corrective action for the next offering:

For maintaining the good quality of the teaching, we keep the treatment for the student in the next semester.

Continuous Improvement Analysis:

In this semester, the continuous improvements are implemented by introduction of term project that cover all material from analysis to the design in control systems engineering. For enrichment of the course material, the computer programming is utilized.

D. Fall 2014:

Suggested corrective action of the previous offering and their results:

We keep the treatment student by assigning a project and conducting tutorial.

Current semester assessment:

The quantitative result slightly decreases comparing with the last offering's result. However, this decreasing is still normal.

Suggested corrective action for the next offering:

Since only slightly decreasing the assessment result, we keep the treatment to the student by assigning a project that utilize the gained knowledge the course. We also keep conducting the tutorial to help the student to face their exams.

Continuous Improvement Analysis:

This semester, there is a slightly decrease in the index of the quantitative result. It is expected the class achievement will be increasing in the next offering.

Aside from assessment for the attainment course to its PLO, we also conducted the questioner to study the student opinions regarding the course and its instructor in each offering. There are two tolls for this purpose, which are the course comparative analysis and instructor comparative analysis. The students fill the questioners before they take the final exams. The samples of these questioners are depicted in Table 5 and 6 for Fall 2014. The score is based on the range of 1 (very unsatisfied) to 5 (excellent). We can see the students have a positive feedback regarding the course and its instructor. The average of grade is higher compare to other courses in the Electrical Engineering department and the whole collage of engineering.

Table 5: Sample of course comparative analysis (Fall 2014)

Question	Course		Department (Mean)	College (Meacn)
	Male (Mean)	Female (Mean)		
The course objectives were clearly explained	4.83	4.47	4.27	4.20
The course outline was consistently followed	4.67	4.67	4.26	4.21
Expectations for learning in this course were clearly communicated	4.67	4.40	4.20	4.10
There was close agreement between the stated course objectives and what was actually covered	4.83	4.53	4.30	4.21
Evaluation methods were clearly explained (rubrics/marking schemes given in advance of assignment and explained to the students)	4.83	4.47	4.29	4.16
The evaluation methods used in this course were fair and appropriate	4.67	4.47	4.15	4.07
The assignment in the course were clearly related to the course objectives	4.83	4.60	4.19	4.14
The requirements of the course (projects, papers, exams) were adequately explained	4.83	4.53	4.19	4.12
Course materials were presented in an organized manner	4.83	4.67	4.29	4.20
Students were invited to share their ideas and knowledge	4.83	4.67	4.18	4.09
The general climate in this course was good for learning	4.67	4.53	4.16	4.14
In general, the level of difficulty in this course was appropriate	4.83	4.40	3.99	3.95

Table 6: Sample of instructor comparative analysis (Fall 2014)

Question	Course		Department (Mean)	College (Mean)
	Male	Female		
Treated students with respect	5.00	4.87	4.50	4.38
Was helpful to students seeking advice	4.83	4.47	4.35	4.25
Was available to students outside of class	4.83	4.67	4.26	4.15
Provided useful feedback on my progress in the course	4.83	4.53	4.12	4.05
Stimulated my interest in the course	4.83	4.33	4.07	3.99
Conducted class sessions in an organized manner	4.83	4.60	4.35	4.18
Used teaching technology (e.g., Blackboard, audio-visual presentations, PowerPoint presentation, email) in an effective and appropriate way	4.83	4.87	4.41	4.27
Overall, the instructor's explanations were and understandable	4.83	4.47	4.24	4.13

IV. CONCLUSION

The assessment results for the course of Control Systems (ELEC 431) in Electrical Engineering Department of United Arab Emirates University for the PLO [c] has been presented. The results are analyzed from Fall 2011-Fall 2014. There were increasing of the attainment from the student from year-to-year. We have also presented course and instructor comparative studies in Fall 2014. The results showed the average comparative studies for the course are higher compare to the comparative studies in department and in the collage of engineering.

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Addy Wahyudie received the B. Eng. degree in electrical engineering (majoring control systems) with cum-laude distinction in 2002 from Gadjah Mada University, Indonesia, the M. Eng. in Electrical Engineering from Chulalongkorn University in 2005, Thailand, and the D. Eng degree in electrical engineering from Kyushu University, Japan, in 2010. From 2005-2011, He was a lecturer in the Electrical Engineering Department of Gadjah Mada University. In August 2011, he joined United Arab Emirates University as Assistant Professor. His research interests include control systems theory (robust control, intelligent control, model predictive control) and its application in electromechanical and renewable energy systems (Ocean wave energy).